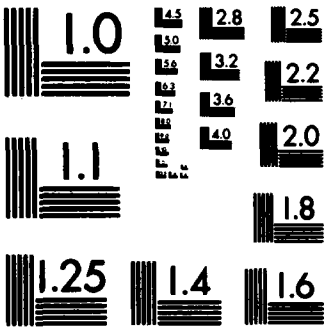
AD-A134 113 FLAME EFFICIENCY STABILIZATION AND PERFORMANCE IN PREVAPORIZING/PREMIXING.. (U) PURDUE UNIV LAFAYETTE IN COMBUSTION LAB A M MELLOR ET AL. OCT 81 PURDU-CL-81-04 1/1

UNCLASSIFIED AFOSR-TR-83-0741 AFOSR-77-3446 F/G 21/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AFOSR-TR- 83-0741

AD-A134113

FLAME EFFICIENCY, STABILIZATION AND PERFORMANCE IN PREVAPORIZING/PREMIXING COMBUSTORS

A. M. MELLOR, C. L. PROCTOR, AND A. G. NEIN

The Combustion Laboratory
School of Mechanical Engineering
Purdue University
West Lafayette, Indiana

AFOSR
Final Report [redacted]-77-3446

1 December 1977 - 30 September 1981

Approved for public release; distribution unlimited.

DTIC
ELECTE
OCT 26 1983
S D
D

October 1981

DTIC FILE COPY

83 10 04 087

Qualified requestors may obtain additional copies from the Defense Technical Information Service.

Conditions of Reproduction

Reproduction, translation, publication, use and disposal in whole or in part by or for the United States Government is permitted.

Accession For	
NTIS GRA&I	X
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
NOTICE OF TRANSMITTAL TO DTIC
This technical report has been reviewed and is approved for public release IAW AFR 190-12.
Distribution is unlimited.
MATTHEW J. KERPER
Chief, Technical Information Division

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFOSR-TR- 83-0741	2. GOVT ACCESSION NO.: AD-A134113
3. RECIPIENT'S CATALOG NUMBER:	
4. TITLE (and Subtitle): FLAME EFFICIENCY, STABILIZATION AND PERFORMANCE IN PREVAPORIZING/PREMIXING COMBUSTORS	5. TYPE OF REPORT & PERIOD COVERED: Final Report 1 Dec 77 - 30 Sep 81
	6. PERFORMING ORG. REPORT NUMBER: PURDU-CL-81-04
7. AUTHOR(s): A M MELLOR, C L PROCTOR, and A G NEIN	8. CONTRACT OR GRANT NUMBER(s): AFOSR-77-3446
9. PERFORMING ORGANIZATION NAME AND ADDRESS: THE COMBUSTION LABORATORY, PURDUE UNIVERSITY, WEST LAFAYETTE, IN 47907	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 61102F, 2308 A2
11. CONTROLLING OFFICE NAME AND ADDRESS: AIR FORCE OFFICE OF SCIENTIFIC RESEARCH/NA, BOLLING AFB, DC 20332	12. REPORT DATE: October 1981
	13. NUMBER OF PAGES: iv + 8
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office):	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

PREVAPORIZING/PREMIXING GAS TURBINE COMBUSTORS
FLASHBACK
FLAME STRUCTURE
NUMERICAL FLOWFIELD MODELING
FLAME STABILIZATION

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The flow field, flame structure, and overall combustion process occurring within a prevaporizing/premixing type combustor have been analyzed. Numerical, experimental and semi-empirical techniques were used to examine a simplified axisymmetric burner configuration possessing the fundamental characteristics found in real prevaporizing/premixing combustion systems. Numerical analysis of the non-reacting flow field of the prevaporizing/premixing combustor configuration was performed using an elliptic finite-difference computer code utilizing the k - e turbulence model. Calculations were performed for a

(cont'd p iii)

variety of geometries and inlet flow conditions to the combustor. Gas samples were extracted from within the prevaporizing/premixing combustor for the two flames examined, propane and Jet-A, and analyzed for gaseous components. Temperature and combustion efficiency calculations were made using this information.

Examination of the numerical and experimental information revealed the invariant behavior of the fundamental flow field with respect to operating conditions, Furthermore, the type of combustion (i.e. single or two-phase fuel input into the combustor) did not significantly alter the flow field, but it did change the relative intensities of combustion within established combustion zones.

Data representing overall combustion efficiency of the combustor were examined in conjunction with numerical and experimental information. The present analysis casts doubt on the validity of these data due to gas sampling problems, and work on another program is cited which confirms this result.

Problems of upstream flame propagation were also examined. Straight cylindrical premixing tubes were used in the combustor to reduce the possibility of upstream flame propagation by autoignition or other mechanisms not associated with classicial flashback. The possibility of upstream flame propagation induced by combustor pressure oscillations was also considered. Monitoring of combustor pressure indicated that no flashback occurred due to these oscillations. Propane was selected as the primary test fuel because of its rapid vaporization characteristics; however, Jet-A was also used.

A characteristic time approach was used to analyze the propane data because the flashback process can be viewed as a competition between a fluid mechanic time and a chemical reaction time. Use of this technique revealed that stoichiometric contours exist in the premixing tubes of this system. Flashback occurred along these contours thus making the flashback independent of stoichiometry.

I. Research Objectives

The Purdue/AFOSR program, Flame Efficiency, Stabilization and Performance in Prevaporizing/Premixing Combustors, was designed specifically to address problems of combustion efficiency and flame stabilization (blowoff and flashback) in simplified combustors representative of

- Ramjets
  (dump combustors)
- Advanced Turbojets
  (prevaporizing/premixing
  catalytic).

The following goals were established

- Establish an experimental data base for model validation
- Develop simple quantitative design tools (the characteristic time model)
- Examine the utility of detailed, finite difference, elliptic codes for flow field interpretation

II. Status of the Research

A. Accomplishments

- Experimental data obtained and characteristic time model developed for blowoff in a partially prevaporizing/premixing combustor (Plee et al., 1977; Plee and Mellor 1978a, 1979).
- Experimental data obtained for combustion efficiency in a partially prevaporizing/premixing combustor (Plee et al., 1977).
- Discrete probing of partially prevaporized/premixed flames using two fuels: Propane and Jet A (Ferguson and Mellor, 1980; Proctor, 1981; Proctor and Mellor, 1981).

- Numerical modeling of nonreacting flowfield for prevaporized/premixed combustor geometry using finite difference code, CORA2 (Proctor 1981; Proctor and Mellor, 1981).
- Examination of literature data on flashback (Plee et al., 1977; Plee and Mellor, 1978b).
- Experimental data obtained for flashback in a partially prevaporizing/premixing combustor (Nein, 1981; Nein and Mellor, 1981).

B. Major Results and Conclusions

- Most "flashbacks" reported in the literature are not due to classical flashback (via boundary layers in the fuel preparation tubes) but rather result from flow separation (Plee and Mellor, 1978b).
- Since flashback data obtained in the Purdue program exhibit essentially no dependence on fuel preparation tube stoichiometry, it must be concluded that even for C_3H_8 complete premixing has not been obtained: stoichiometric contours persist in the tube and are the zones of easiest flashback (Nein, 1981; Nein and Mellor, 1981).
- These flashbacks were observed to occur at nearly constant pressure without observation of rumble or other instabilities ($> \pm 1$ psi) (Nein, 1981; Nein and Mellor, 1981).
- Blowoff data were correlated by a characteristic time model which has been generalized to include homogeneous premixed and spray flames (Plee and Mellor, 1979) and recently extended to gas turbine engines (Leonard and Mellor, 1981).
- Contour maps obtained during detailed probing exhibit flame structure in remarkedly good agreement with the cold flow predictions of CORA2, but an unexpectedly low inlet condition on turbulent intensity (0.3%)

must be input to the code (Proctor, 1981; Proctor and Mellor, 1981).

- Early data collected with an area-averaging rake for combustion efficiency (Plee et al., 1977) did not allow comparison of inlet and outlet equivalence ratios for the flames due to instrument limitations (no O_2 or CO_2 analyzers). The inability to correlate these data with the characteristic time models is now attributed to the rake's not mass-averaging its measurements and for Jet A not sampling liquid fuel. Thus the data are suspect. This conclusion is based on the extreme velocity stratification predicted by CORA2 and suggested by the experimental contour maps (Proctor, 1981; Proctor and Mellor, 1981), single point probing at the exhaust plane of another combustor configuration (Leonard, 1981), and equivalence ratio checks on the AFOSR combustor during a DOE program (Tong, 1981).

C. References

Ferguson, C. R. and Mellor, A. M. (1980), "Probing a premixed/prevaporized type of combustor," AIAA Paper No. 80-0285.

Leonard, P. A. (1981), "Correlation of the effects of fuel type on gas turbine combustor efficiency," Ph.D. Thesis, Mech. Eng., Purdue University.

Leonard, P. A. and Mellor, A. M. (1981), "Correlation for lean blowoff for gas turbine combustors using alternative fuels," WSS/CI Paper No. 81-22; to appear in AIAA J. Energy.

Nein, A. G. (1981), "Flashback in premixing/prevaporizing combustion systems," M.S.M.E. Thesis, Mech. Eng., Purdue University.

Nein, A. G. and Mellor, A. M. (1981), "Flashback in partially prevaporized/premixed combustion systems," to be submitted to AIAA J. Energy.

Plee, S. L. and Mellor, A. M. (1978a), "Flame stabilization in simplified prevaporizing, partially vaporizing and conventional gas turbine combustors," AIAA J. Energy 2, 346-353.

Plee. S. L. and Mellor, A. M. (1978b), "Review of flashback reported in prevaporizing/premixing combustors," Combust. Flame 32, 193-203.

Plee, S. L. and Mellor, A. M. (1978), "Characteristic time correlation for lean blowoff of bluff-body-stabilized flames," Combust. Flame 35, 61-80.

Plee, S. L., Schmidt, D. A. and Mellor, A. M. (1977), "Flame efficiency, stabilization and performance in prevaporizing/premixing combustors," AFOSR TR 78-0736 (ADA 053635).

Proctor, C. L., II (1981), "Interpretation of a characteristic time model for performance of a prevaporized/premixed combustor," Ph.D. Thesis, Mech. Eng., Purdue University.

Proctor, C. L. II and Mellor, A. M. (1981), "Analysis of the structure of partially prevaporized/premixed flames," to be submitted to Combust. Flame.

Tong, E. H. (1981), "The performance of SRCII fuels in gas turbine combustors," M.S.M.E. Thesis, Mech. Eng., Purdue University.

III. Publications

A. Published

Plee, S. L. and Mellor, A. M., "Review of flashback reported in prevaporizing/premixing combustors," Combust. Flame 32, 193-203, (1978).

Plee, S. L. and Mellor, A. M., "Flame stabilization in simplified prevaporizing, partially vaporizing and conventional gas turbine combustors," AIAA J. Energy 2, 346-353, (1978).

Mellor, A. M., "Turbulent-combustion interaction models for practical high intensity combustors," pp. 377-387, Seventeenth Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, (1979), (invited).

Plee, S. L. and Mellor, A. M., "Characteristic time correlation for lean blowoff of bluff-body-stabilized flames," Combust. Flame 35, 61-80, (1979).

Ferguson, C. R. and Mellor, A. M., "Practical problems in turbulent reacting flow," pp. 45-64, Turbulent Reacting Flows, Springer-Verlag, Berlin, (1980), (invited).

Mellor, A. M., "Semi-empirical correlations for gas turbine emissions, ignition and flame stabilization," AGARD CP No. 275, Combustor Modeling, (1980), (invited); Prog. Energy Combust, Sci. 6, 347-358, (1980), (invited).

Ferguson, C. R. and Mellor, A. M., "Probing a premixed/prevaporized type of combustor," AIAA Paper No. 80-0285, (1980).

B. In Press

Mellor, A. M., "Soot studies in gas turbine combustors and other turbulent spray flames," Prepared for the General Motors Research Laboratories Symposium on Particulate Carbon, Formation during Combustion, (1980), (invited).

C. In Preparation

Nein, A. G. and Mellor, A. M., "Flashback in partially prevaporized/premixed combustion systems," to be submitted to AIAA J. Energy.

Proctor, C. L. II and Mellor, A. M., "Analysis of the structure of partially prevaporized/premixed flames," to be submitted to Combust. Flame.

IV. Advanced Degrees Awarded

Plee, S. L., "Characteristic time model for flame stabilization in simplified continuous combustion systems," Ph.D., May 1978.

Schmidt, D. A., "Combustion efficiency as affected by fuel type in confined disc stabilized flames and prevaporizing/premixing combustors," M.S., December 1978.

Wyatt, W. R., "Preliminary flow measurements in a model turbine combustor," M.S., December 1979.

Nein, A. G., "Flashback in premixing/prevaporizing combustion systems," M.S., December 1981.

Proctor, C. L. II, "Interpretation of a characteristic time model for performance of a prevaporized/premixed combustor," Ph.D., December 1981.

V. Interactions

A. Meeting Presentations

Mellor, A. M., "A phenomenological model for gas turbine emissions," DOE/Division of Power Systems Workshop on Modeling of Combustion in Practical Systems, 4-6 January 1978, Los Angeles, CA, (invited).

Plee, S. L., "Flame stabilization in a simplified prevaporizing, partially vaporizing and conventional gas turbine combustor," AIAA/SAE 14th Joint Propulsion Conference, 25-27 July 1978, Las Vegas, NV.

Mellor, A. M., "Turbulent combustion interaction models for practical high intensity combustors," Seventeenth Symposium (International) on Combustion, 20-25 August 1978, Leeds, England, (invited).

Plee, S. L., "Characteristic time correlation for lean blowoff of bluff body stabilized flames," 1978 Fall Meeting, Western States Section/The Combustion Institute, 16-17 October 1978, Laguna Beach, CA.

Mellor, A. M., "Semi-empirical correlations for gas turbine emissions, ignition, and flame stabilization," 54th(B) Specialists' Meeting, Propulsion and Energetics Panel, AGARD, 3-5 October 1979, Cologne, Federal Republic of Germany, (invited).

Ferguson, C. R., "Probing a premixed/prevaporized type of combustor," AIAA 18th Aerospace Sciences Meeting, 14-16 January 1980, Pasadena, CA.

Mellor, A. M., "Soot studies in gas turbine combustors and other turbulent spray flames," General Motors Research Laboratories Symposium, 14-15 October 1980, Warren, MI.

B. Consulting to other AF and DOD Laboratories

The AFOSR grant, in part, resulted in two consulting contracts to Wright-Patterson AFB under their Senior Investigator Program. Each contract is described briefly below.

"Support of AFAPL's In-House Combustion Experiments"
Air Force Aero Propulsion Laboratory
12/77-9/79

Originally a consulting program to the APL combustion tunnel work, in the areas of experiment design, modeling, and classical and optical diagnostics, this program also included design and fabrication of several water-cooled gas sampling probes. Limited measurements were made in a disc-in-duct configuration to compare results from the various probes, which were then supplied to AFAPL for their in-house program. It was found that probes with similar quench rates due to the water cooling gave essentially equivalent results for gaseous emissions.

"Turbopropulsion Combustion Technology Assessment"
Air Force Aero Propulsion Laboratory
6/78-10/79

In conjunction with APL turbopropulsion combustion and fuels personnel, a survey questionnaire was prepared for ATEGG engine contractors to assess the state-of-the-art and particular research needs in the areas of alternate fuels, and combustor and afterburner design for military engines. After extensive briefings to a DOD-wide audience by each of the five selected contractors, a comprehensive review of the responses was prepared, and a suggested five-year turbopropulsion combustion research plan was formulated.

VI. Discoveries and Inventions

None

END

FILMED

11-83

DTIC